Saturn V Stage I (S-IC) Overview
Objectives

- Become familiar with the Saturn V Stage I (S-IC) major structural components:
  - Forward Skirt
  - Oxidizer Tank
  - Intertank
  - Fuel Tank
  - Thrust Structure
- Gain a general understanding of the Stage I subsystems:
  - Fuel
  - Oxidizer
  - Environmental Control
  - Electrical
  - Instrumentation
  - Flight Control
  - Control Pressure
  - Ordinance
- 138 feet/42 meters high

S-IC Stage Structure

- 138 feet/10 meters in diameter
- 33 ft/10 m in diameter
- Five F-1 engines manufactured by Rocketdyne
- Total Thrust = 7,610,000 lbs/3,451,837 kilograms
- Two propellants
  - Liquid Oxygen (LOX)
  - Fuel spell out (RP-1)
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  3,451,838 kilograms
S-IC Stage Structure

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- Total Thrust = 7,610,000 lbs/3,451,838 kilograms
- Two propellants
  - Liquid Oxygen (LOX or RJ-1)
  - Fuel/Kerosene (RP-1)
- Forward Skirt
- Oxidizer Tank
- Intertank Section
- Fuel Tank
- Thrust Structure
- Provides connecting link for First & Second Stage

- Accommodates:
  - Forward umbilical plate
  - Electrical canisters
  - Venting of LOX tank
- Held 331,000 gallons/1,252,971 liters of liquid oxygen

- -297° F (-183° C)

- Contained ring baffles for structural stability
  - Reduced LOX sloshing
  - Supported Helium (He) bottles
- Provided structural continuity between LOX & Fuel Tank
- LOX fill & drain interface to intertank umbilical
- Vented the fuel tank
Fuel Tank

- Held 203,000 gallons/768,438 liters of RP-1

- Antislosh ring baffles on inner walls

- Antivortex ring baffles on lower bulkhead

- Five LOX ducts run from LOX tank through fuel tank
- Provided support for:
  - Base heat shield
  - Engine fairings & fins
  - Propellant lines
  - Retrorockets
  - Environmental control ducts
- Lower thrust ring had four hold-down points to restrain vehicle
Stage I Subsystems

- Fuel System
- Oxidizer System
- Environmental Control System
- Electrical System
- Instrumentation System
- Flight Control System
- Control Pressure System
- Ordinance System
Fuel System

- Consisted of fuel tank, fuel feed lines, pressurization system, fill and drain components, & fuel conditioning system

- Held 203,000 gallons/768,438 liters of kerosene

- Provided 1,350 gallons/5,110 liters of fuel per second

- 10 fuel suction lines
Fuel System: Fuel Fill & Drain System

- Filled through six-inch Fill & Drain Line
- Fill & Drain Valve provided fuel shutoff
- Temperature Sensors used to compute fuel density
- Tank level filled to 102%, then the Fuel Loading Probe indicated overload
- After adjustments, Fill & Drain Valve closed
- 10 Fuel Suction Lines
  - Two/engine
  - Supplied fuel to F-1 engine inlets
Fuel System: Fuel Feed

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  - Two/engine
  - Supplied fuel to F-1 engine inlets

- Each line had pneumatically controlled Prevalve
Fuel System: Fuel Conditioning

- Bubbled GN$_2$ through feed lines to prevent fuel temperature stratification prior to launch
- Wire mesh Filter prevented discharge of contaminants
- Check Valve prevented fuel from entering GN$_2$ lines
- Orifice provided proper GN$_2$ flow into each fuel duct
Fuel System: Fuel Level Sensing & Engine Cutoff

- Fuel measured by four fuel Slosh Probes & one Liquid Level Probe
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- Fuel measured by four fuel Slosh Probes & one Liquid Level Probe

- In case fuel depleted before LOX, fuel system will shut down engine
  - Cutoff Sensor provided signal voltages to shut off fuel
  - Cutoff Sensor initiated engine cutoff as fuel falls below two sensing points on probe
Fuel System: Fuel Pressurization System

- Four high pressure He Storage Bottles in LOX Tank pressurized Fuel Tank ullage
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**Fuel System: Fuel Pressurization System**

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- Dump Valve for emergencies
Fuel System: Fuel Pressurization System

- Four high pressure He Storage Bottles in LOX Tank pressurized Fuel Tank ullage
- High Pressure Line used for filling Storage Bottles
- Filter in He fill line prevented contaminants from entering Flight Pressurization System
- Dump Valve for emergencies
- Five Solenoid Valves in parallel to control He flow to Fuel Tank ullage
Fuel System: Fuel Pressurization System

- Cold He Duct routed He from Flow Controller to Cold He Manifold
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- He carried through He Distributor & into Fuel Tank
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- Three Pressure Switches monitored and controlled Fuel Tank pressurization
Stage I Subsystems

- Fuel System
- Oxidizer System
- Environmental Control System
- Electrical System
- Instrumentation System
- Flight Control System
- Control Pressure System
- Ordnance System
Consisted of LOX tank, fill & drain components, LOX suction lines, pressurization subsystem

Tank contained ring baffles to prevent sloshing

Cruciform baffle limited swirling

Four LOX liquid level probes monitored LOX level in tank
Oxidizer System: LOX Fill & Drain System

- Two six-inch Fill & Drain Lines
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- Level Probe sensed full tank
Oxidizer System: LOX Fill & Drain System

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Oxidizer System: LOX Fill & Drain System

- Two six-inch Fill & Drain Lines
- Level Probe sensed full tank
- Third line available to fill tank through Inboard Suction Line
- LOX boiled to maintain temperature of -297°F (-183°C)
- Fill & Drain Valves opened to complete drainage of LOX Tank
Oxidizer System: LOX Delivery

- Five 17-inch Suction Lines

Inside LOX Tunnels, air acted as insulation between LOX lines & fuel lines. Cutoff sensors assured safe engine shutdown. Prevalves can stop flow of LOX to engine in emergency.
Oxidizer System: LOX Delivery

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Oxidizer System: LOX Conditioning

- LOX cannot exceed -297\(^\circ\) F (-183\(^\circ\) C) or it will result in gaseous oxygen (GOX).

- Emergency bubbling corrected GOX situation
  - Bubbling technique sent He into five Suction Lines to cool LOX.

- Filter Valves & Orifices controlled flow of He into Suction Lines.
Oxidizer System: LOX Pressurization

- Pressurization occurred at T-45 seconds
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- He was supplied by GSE through He Ground Connection
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- He was supplied by GSE through He Ground Connection

- He proceeded up GOX line into LOX tank through GOX Distributor

- Pressure Duct monitored flow of He
GOX was added to LOX Tank for pressurization during flight.

Diagram:
- Oxidizer System: LOX Pressurization
- GOX Distributor
GOX was added to LOX Tank for pressurization during flight.

Portion of LOX was diverted into Heat Exchangers where it was transformed into GOX.
Oxidizer System: LOX Pressurization

- GOX was added to LOX Tank for pressurization during flight
- Portion of LOX was diverted into Heat Exchangers where it was transformed into GOX
- GOX flowed from Heat Exchanger to GOX Manifold through Flow Control Valve, up GOX Line, & into LOX Tank through the GOX Distributor
- Fuel System
- Oxidizer System
- **Environmental Control System**
- Electrical System
- Instrumentation System
- Flight Control System
- Control Pressure System
- Ordnance System
Environmental Control System (ECS)

- Forced conditioned air into the Forward Skirt & Thrust Structure

- 20 minutes before cryogenic loading, flow switched from conditioned air to gaseous nitrogen (GN$_2$)

- GN$_2$ flow terminated at umbilical disconnect (liftoff)

- Distribution Manifolds
  - Distributed air & GN$_2$ to Instrumentation Canisters in Forward Skirt
  - Vented air and GN$_2$ through Orifices into Thrust Structure
- Fuel System
- Oxidizer System
- Environmental Control System
- **Electrical System**
- Instrumentation System
- Flight Control System
- Control Pressure System
- Ordnance System
- Two independent 28-volt DC power systems located in the Forward Skirt
- Battery # 1 – Operational power system battery
  - Supplied power to valve controls, venting systems, pressurization systems, sequencing & flight control
  - Controlled solenoids
- Battery # 2 – Measurement power system battery
  - Supplied power to telemetry systems, transducers, multiplexers, & transmitters
- **Main Power Distributor**: housed relays, power transfer switch, & other electrical equipment

- **Relays**: controlled time-programmed circuits

- **Sequence & Control Distributor**
  - Accepted command signals from Switch Selector
  - Commanded staging functions
- Propulsion Distributor contained monitor & control circuits for propulsion system
- Thrust OK Distributor contained circuits that shut down engines when thrust was inadequate
- Timer Distributor contained circuits to delay operation of relay valves
- Measuring Power Distributor
  - Contained electrical buses
  - Routed data from measuring racks
  - Served as measurement signal junction box
  - Switched data between hardwire & telemetry
- Fuel System
- Oxidizer System
- Environmental Control System
- Electrical System
- **Instrumentation System**
- Flight Control System
- Control Pressure System
- Ordnance System
Instrumentation System

- Reported information on stage systems & components
- Provided data on internal & external environments
- Monitored approximately 900 Stage I (SI-C) measurements
- Measurements were telemetered by
  - Coaxial cable to GSE preflight
  - Radio Frequency (RF) transmission to ground stations during flight
Instrumentation System: Measurement

- Used transducers, signal conditioners, measuring rack assemblies, measuring distributors, & the onboard portion of the remote automatic calibration system

- Measured acceleration, acoustics, current, flow, flight angles, valve position, pressure, RPM’s, stress, temperature, vibration, & separation
Instrumentation System: Telemetry

- Method to remotely monitor flight data through RF links

- Six RF links
  - F1, F2, F3, S1, S2, & P1

- RF Assemblies & Tape Recorder located in Forward Skirt

- Remaining components located in Thrust Structure
Instrumentation System: Telemetry

- Links F1, F2, & F3
  - Transmitted narrow-band, frequency-type data such as strain gages, temperature gages, & pressure gages
  - Could handle 234 measurements on time-sharing basis & 14 measurements transmitted continuously

- Links S1 & S2
  - Transmitted wide-band, frequency-type data generated by vibration sensors
  - Each provided 15 continuous channels or max of 75 multiplexed channels

- Telemeter P1
  - Transmitted either pulse code-modulated or digital type data
Offset Doppler Tracking (ODOP) System

- Measured rate of motion the vehicle was moving away from/toward a Tracking/Receiving Station
- Signal was received by transponder, modified, and retransmitted back to ground
- Retransmitted signals were received by three Receiving Stations
- Separate antennas on stage were used for receiving and retransmitting the signals
Instrumentation System: Separation System

- Redundant ignition system activated separation of First Stage from Second Stage

- Command signal for arming & firing initiation systems were generated by Instrumentation Unit (IU) computer
  - The IU is located above the Third Stage (S-IVB) and below the Apollo Spacecraft (CSM/LM)

- After LOX depletion, the IU signaled the Switch Selector and Sequence & Control Distributor to activate the exploding bridgewire firing units (explosive devices) to initiate the staging sequence
Visual Instrumentation: Film Cameras

- Four film cameras, each in a recoverable capsule

- Two LOX tank-viewing Pulse Cameras, provided motion pictures to show:
  - Behavior of LOX
  - Possible wave or slosh motions
  - Cascading or waterfall effects of liquid from internal tank structure

- Two Strobe Lights illuminated interior of LOX tank for Pulse Cameras

- Two direct-viewing Stage Separation Cameras

- The nine ft (3 m) Fiber Optics, the coupling lens, and the objective lens connected the remotely located camera capsules and flash head
Visual Instrumentation: Television System

- Airborne Television System provided in-flight, real-time visual performance information on all five First Stage F1 engines

- Also stored televised pictures from fueling through First Stage separation

- System utilized two split fiber optic viewing systems & two cameras

- Fiber optic bundles transmitted images to the cameras located in Thrust Structure
Stage I Subsystems

- Fuel System
- Oxidizer System
- Environmental Control System
- Electrical System
- Instrumentation System
- **Flight Control System**
- Control Pressure System
- Ordnance System
Flight Control System: Fluid Power System

- Used RP-1 and RJ-1 as hydraulic fluid
  - Same type of fuel used for stage fuel system
- Ground supply of RJ-1 routed to all five F1 engines
- After ignition, RP-1 routed from High Pressure Fuel Duct to Servoactuators
- Center Engine directed hydraulic fluid through Feedline & 4-way Hydraulic Control Valve to supply pressure to closing ports of Gas Generator, Main Fuel Valves, & Main LOX Valves
- The four outboard engines directed RJ-1 through Servoactuators to ground Checkout Valve where it was returned through coupling to ground supply
Flight Control System: Hydraulic Servoactuator

- Power control unit for converting electrical command signals & hydraulic power into mechanical outputs to gimbal engines
- The engine gimbaling was a closed loop system
  - IU received inputs from its guidance system and sent signals to Servoactuators to gimbal the engines
  - Potentiometer sensed Servoactuator position and transmitted that feedback (engine piston position) to the IU
  - IU modified effect of control signal to continue to gimbal the engines in the required direction
Stage I Subsystems

- Fuel System
- Oxidizer System
- Environmental Control System
- Electrical System
- Instrumentation System
- Flight Control System
- Control Pressure System
- Ordnance System
- Supplied pressurized GN\textsubscript{2} to pneumatically actuate propellant system valves & purge the F-1 engines

- **Onboard Control Pressure System** – contained high pressure nitrogen storage bottle, an umbilical coupling & tubing assembly for filling bottle, manifold assembly, & control valves at terminal ends of nitrogen distribution lines

- **Ground Control Pressure System** – provided direct ground pressure supply for First Stage pneumatically-actuated valves that were involved with propellant fill/drain & emergency engine shutdown system operations

- **Onboard Purge Pressure System** – expelled propellant leakage
Stage I Subsystems

- Fuel System
- Oxidizer System
- Environmental Control System
- Electrical System
- Instrumentation System
- Flight Control System
- Control Pressure System
- Ordnance System
Ordnance System: Propellant Dispersion System (PDS)

- Terminated flight of Saturn V if it strayed from flight path or if it became a safety hazard

- PDS was a dual channel, parallel redundant system composed of two segments
  - Radio frequency segment received, decoded, & controlled propellant dispersion commands
  - Ordnance train segment consisted of two exploding bridgewire (EBW) firing units, two EBW detonators, one safety & arming (S&A) device, six confined detonating fuse (CDF) assemblies, two CDF tees, two CDF/flexible linear shaped charge (FLSC) connectors, & two FLSC assemblies
Ordnance System: PDS

For detailed view, select presentation under References below
Ordnance System: Safety and Arming Device (S&A)

- Remotely controlled electro-mechanical ordnance device
- Used to make safe & to arm S-IC, S-II, and S-IVB stage PDS’s
- Completed & interrupted explosive train by remote control
- Provided position indications to remote monitoring equipment
Ordnance System: Retrorockets

- The eight retrorockets provided separation thrust after Stage S-IC burnout.

- Propelled Stage S-IC away from the rest of the launch stack as it progressed through to Stage II.

For detailed view, select presentation under References below.
Saturn V Stage I Summary

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  - Forward Skirt
  - Oxidizer Tank
  - Intertank
  - Fuel Tank
  - Thrust Structure

- Gain a general understanding of the Stage I subsystems:
  - Fuel
  - Oxidizer
  - Environmental Control
  - Electrical
  - Instrumentation
  - Flight Control
  - Control Pressure
  - Ordinance
Apollo Mission Familiarization for Constellation Personnel

- Apollo-Saturn Wiki

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